Effects of simulated rain on the effluent from lysimeters with acid, shallow soil, rich in organic matter

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The effects of acid rain on freshwater chemistry are likely to be most significant in areas with acid, shallow soils overlying siliceous bedrock. Due to the low content of exchangeable "base" metal cations, such areas have a low buffering capacity towards acids and retention of anions is usually low.

Lysimeters (55 x 35 cm) with "undisturbed" soil monoliths with vegetation dominated by heather *(Calluna vulgaris)* or moorgrass *(Molina coerulea)* were supplied with 1350 mm year^{-1} of simulated rain. The soil is from an area in Southern Norway exposed to acid rain. The soil in the lysimeters are 14 - 24 cm deep and includes the total soil profile down to the lithic contact (Tab. 1). The effect of "acid rain" (pH 4.3) on the chemical composition of the effluent was compared to the effect of "normal rain" (pH 5.3) (Tab. 2). During the first year (1977/78) the simulated rain was applied twice a week in equal amounts and with constant pH. The second year (1978/79) the "rain" was applied episodically (Fig. 1). The "normal rain" had a constant pH of 5.3 whereas the "acid rain" had a pH varying between 3.8 and 5.3 (volum weighted average 4.3).

The experiment include two replications.

A few weeks after commencing the application of simulated rain the difference between treatments in SO_4^{2-} concentration approached the difference in the two "rain" qualities (22 μM) (Fig. 2). This difference was maintained during the first year (1978). When the episodic application of simulated rain started in Nov. 1978 the leaching pattern became much more variable. After a frost period from Dec. 1978 through Febr. 1979 the leaching of SO_4^{2-} increased significantly and the difference between the treatments was enhanced. A drought period in May and June 1979 gave a similar effect. The average differences in concentrations between the treatments amounted to 17 μM from the moorgrass lysimeters and 29 μM from the heather lysimeters (Tab. 3).

The effluent from the heather lysimeters had a pH between 4.5 and 3.6, whereas the pH of the effluent from the moorgrass lysimeters was between 5.5 and 4.4 (Fig. 3). The effluent from both series of lysimeters was most acidic between June and Nov., least acidic between Dec. through May. The seasonal variation in acidity of the effluent amounted to approximately 150 μM from the heather lysimeters and 35 μM in the moorgrass lysimeters. The difference in "rain" quality produced a difference in the pH of the effluent which usually was less than 0.1 pH unit, but sometimes about 0.2 pH units. The more acidic effluent from the heather lysimeters involved that the H^+ concentration was more affected by the "rain" quality in these lysimeters than the effluent from the moorgrass lysimeters. The average difference in H^+ concentrations between the treatments was 3 μM in the moorgrass lysimeters and 7 μM in the heather lysimeters (Tab. 3).

In the moorgrass effluent the highest concentrations of Al were found between Aug. and Nov. and also after the frost period from Dec. 1978 through Febr. 1979 (Fig. 4). The effluent from the heather had the highest Al concentrations from June to Nov. The effect of rain quality on the Al concentration was on average 7μM in the effluent from the heather and negligible in the moorgrass (Tab. 3).

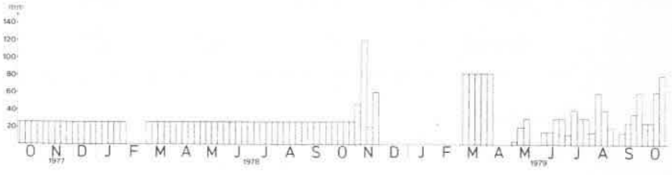

Fig. 1. Distribution of simulated rain applied to the lysimeters. Both in 1978 and 1979 the annual amount of simulated rain was 1350 mm.

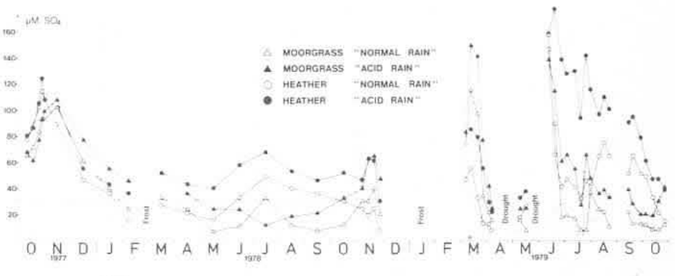

Fig. 2. SO_4^{2-} concentration (μM) in the effluent.

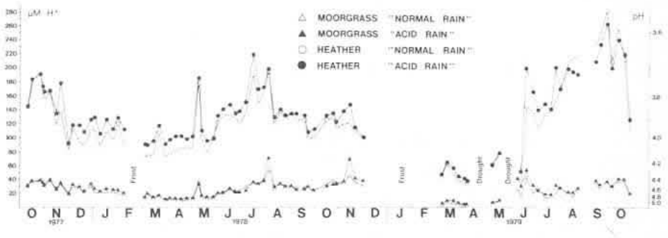

Fig. 3. H^+ concentration (μM) and pH in the effluent.

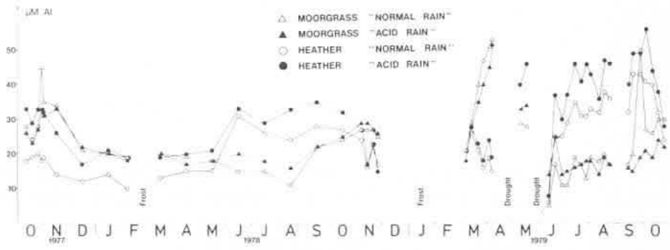

Fig. 4. Al concentration (μM) in the effluent.

In spite of a significant difference in SO_4^{2-} leaching between the treatments the amount of H^+ + Al of the effluent of the moorgrass lysimeters was not significantly affected by the acidity of the simulated rain (Tab. 3). The cations affected by the treatments and causing the buffering of the effluent were K^+, Mg^{2+}, NH_4^+ and to a less extent Ca^{2+}. There were apparently more cations than anions in the effluent, probably because some of the elements, primarily Al and Ca, were complexed.

Table 1. Some chemical properties of the soil.

Vegetation	Depth cm	Loss on ignition %	pH H_2O 1:2.5	Total acidity me kg^{-1}	Exchangeable acidity me kg^{-1}	Exchangeable ions 1 M NH_4OAc pH 7 me kg^{-1} Na	K	Mg	Ca	Extractable Al 1 M KCl mmol kg^{-1}	Extractable SO_4 0.01M $Ca(H_2PO_4)_2$ mmol kg^{-1}
Moorgrass[1)]	Upper 5 cm	89.3	4.4	700	223	1.7	10.5	11.6	18.8	68.0	1.9
	Lowest 5 cm	18.6	4.6	228	65	0.5	2.7	1.1	0.8	23.4	0.2
Heather[1)]	Upper 5 cm	90.8	4.0	1000	233	2.3	15.2	35.4	110.5	8.0	1.3
	Lowest 5 cm	58.4	4.0	577	139	0.9	6.6	5.0	5.0	38.7	0.7

[1)] Mean of 4 samples

Tab. 2. Chemical composition of the simulated rain (µM).

	"Normal rain" pH 5.3	"Acid rain" pH 4.3	"Acid rain" in episodes[1)]
H^+	5.0	50.1	5.0
Na^+	56.1	56.1	56.1
K^+	3.1	3.1	3.1
Mg^{2+}	7.4	7.4	7.4
Ca^{2+}	6.0	6.0	6.0
NH_4^+	16.6	29.9	10.0
NO_3^-	6.0	30.0	10.0
Cl^-	77.0	77.0	77.0
SO_4^{2-}	9.3	31.5	5.2

[1)] H^+, SO_4^{2-}, NH_4^+ and NO_3^- were adjusted with a solution 0.050 M with respect to H_2SO_4 and 0.042 M with respect to NH_4NO_3

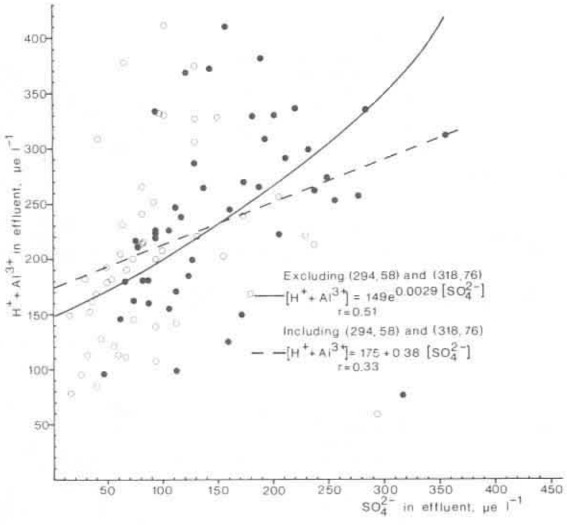

Fig. 5. Relationship between SO_4^{2-} and the sum of Al (treated as Al^{3+}) and H^+ concentration (µe l^{-1}) in the effluent from the heather lysimeters.
○ are from lysimeters supplied with "normal rain".
● are from lysimeters supplied with "acid rain".

Table 3. Average concentrations for the years 1978 and 1979 of SO_4^{2-}, H^+ and Al in µM in the effluent from the two series of lysimeters.

		Moorgras		Heather	
		pH 5.3	pH 4.3	pH 5.3	pH 4.3
SO_4^{2-}	µM	38	55	47	76
H^+	"	24	27	133	140
Al	"	25	24	25	32

The content of $H^+ + Al$ in the effluent from the heather lysimeters was affected by the acidity of the simulated rain (Tab. 3). If Al is treated as Al^{3+}, the sum of $H^+ + Al^{3+}$ represents an important proportion of the total acidity of the effluent. In Fig. 5 the sum of H^+ and Al^{3+} is plotted against the SO_4^{2-} concentration in the effluent from the heather lysimeters. The plots (different dates) are very scattered, but there is a highly significant correlation between the SO_4^{2-} concentration and the concentration of $H^+ + Al^{3+}$. The regression analyses indicate that an increase in the SO_4^{2-} leaching of one µe l^{-1} from the heather lysimeters involves an increase in the leaching of $H^+ + Al^{3+}$ of approximately 0.6 to 0.4 µe l^{-1}. This implies that a reduction in the SO_4^{2-} leaching equal to 44 µe l^{-1} ("acid rain" minus "normal rain") might reduce the content of $H^+ + Al^{3+}$ in the effluent from this soil of 24 to 17 µe l^{-1}. This is slightly less than the difference given in Tab. 3.

This is SNSF contribution FA 74/80.